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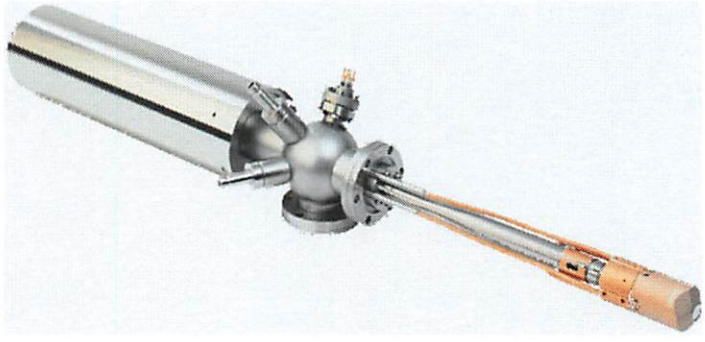

XR50

X-ray Source

Manual

1.7

User Manual for the X-ray Source XR50.

Version 1.7 of the 16.2.2007.

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Chapter

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Chapter

1

Introduction and Safety Hints

The manual describes the installation, initial commissioning, normal operation, and trouble shooting of the XR-50 X-ray source. The standard maintenance procedures for the X-ray source are described in Section 5.

Please note the radiation hints given in section 1.2.2.2 , 'Soft X-ray radiation protection" on page 4.

For the initial setup of the source please refer to:

- "Installation of the X-Ray Source & Power Supply Units" on page 17
- "The Connection Diagram for the X-Ray Source XR-50" on page 36
- "Bakeout of the X-Ray Source" on page 24
- "Initial Setup of the source" on page 21

For the operation procedures please see section 4:

- "Normal Operation" on page 23
- "Switching Off the X-Ray Source" on page 24

1.1 Application, Capability

The XR-50 is a new, high-intensity twin anode X-ray source optimized for XPS (ESCA) experiments. Additionally the source can be used for excitation in Photoinduced Desorption Spectroscopy (PDS).

The standard version of the XR-50 is equipped with a Mg/Al twin anode with two filaments, and offers continuous operation at powers of 300W/400W (Mg/Al). SPECS also offers the option of coating the anode with other elements or, on request, as a single anode for Al or Mg operation.

The mounting flange is DN 38 CF (2 3/4" OD). The installation of an optional linear translation stage allows the cone-shaped nose of the XR-50 to be positioned very close to the sample during operation and to be retracted to provide space for other

techniques or to protect the X-ray source window against contamination. The slender design allows the XR-50 to be used in both spherical or cylindrical analysis chambers.

The XR-50 module (with the water supply and HV protection cover removed) can be baked up to 250°C. "Quick Fit" connectors provide an effective means for safe and rapid removal of the water lines and the HV cable. The anode region of the XR-50 can be differentially pumped via a DN 38 CF (2 3/4" OD) flange. SPECS also offers customized vacuum systems that can easily be adapted to existing UHV equipment. The power supply XRC1000 and the cooling control unit CCX 60 used to operate the XR-50 module are described separately.

1.2 Safety Hints

1.2.1 General

Before any electric or electronic operations please consult "SPECS Safety Instructions" and follow them strictly.

Some tests which may have to be carried out are hazardous. These parts are indicated by a warning label:

!!Attention!!

Beware! Hazardous voltages are present. Lethal high voltages up to 15 kV are applied to the X-ray source. Only persons with the appropriate training are allowed to carry out the installation, adjustment and repair procedures described in this manual. Make measurements only with special insulated tools rated for voltages higher than 20 kV.

All federal, state, company and/or department internal regulations, restrictions, codes, and rules for protection against radiation sources have to be observed during installation and operation of the X-ray source at your site! Consult your radiation control officer in case of any doubt. The user is responsible for the correct labeling of the source and its power supplies, as well as providing safety instructions in the native language of the site!
See also the comments given in section 1.2.2.2 , 'Soft X-ray radiation protection" on page 4.

1.2.2 Special hints

1.2.2.1 HV protection

The XR-50 module uses high voltages up to 15 kV! It is important to comply with the following safety directives:

- Check whether your mains voltage corresponds to the mains setting at the rear panel of the power supplies for the XR-50 (XRC1000 and CCX 60).
- Use only original cables, connectors, and flexible conduits from SPECS. Pay careful attention that all cables and water lines are without mechanical or electrical defects. In case of any doubt, the cable or the water line has to be replaced by an original SPECS part.
- Connect the X-Ray source with HF low impedance cable to the power supply ground. Large contact areas are important. A proper connection will protect the sensitive electronic units of your system.
- Never run the X-ray source without a grounding cable or a loose ground connection!
- All shields and their interlock, remote and other connections must be grounded with a proper HF cable, too!
- Only operate the XR-50 only with a fully closed protection cover and a properly affixed conduit for the HV cable and water supply! Open slits and holes could be a dangerous and violate safety regulations!
- Do not operate the X-ray source unless your system pressure is below 10^{-6} mbar!
- Do not operate the X-ray source without water cooling for the anode. Cooling the housing jacket limits the temperature increase of an irradiated sample during continuous operation.
- Before switching on the power, the electrical and mechanical installation has to be completed. The interlocks for vacuum, water, and HV have to be correctly activated and tested for safe and proper functioning.
- Never short the HV guard or the water interlock system!
- Never operate the power supplies with housing parts removed!
- Connect the XR-50 only when the power supplies are turned off!
- After switching off the power units the operator has to wait a minimum of 3 minutes before opening any connections, the power supplies or the X-ray source protection cover.
- In the event of a water leak at the source, a complete drying of the module, the protection cover, the conduit, and the cables is strongly recommended. Never run the XR-50 module with wet parts inside of the conduit!
- Operating the XR-50 with equipment other than that delivered by SPECS may void your warranty. In case of any doubt please contact the SPECS service department.

1.2.2.2 Soft X-ray radiation protection

Supplementary to the regulations, restrictions, codes, and rules for protection against radiation which have to be observed by the law at the operational site of the XR-50 M SPECS recommend the following hints:

- All ports of the chamber have to be closed by blank flanges or compact UHV components made of stainless steel.

- **WARNING**
  X-ray are emitted by this source!
  Ensure that all view ports are leaded glass or are screened to prevent the radiation of X-rays!

- If larger components made of other materials (e.g. glass) are installed, consult your radiation control officer!
- Pregnant women should announce their situation to the superior or safety inspector!
- All federal, state, company and/or department internal regulations, restrictions, codes, and rules for protection against radiation sources have to be observed during installation and operation of the X-ray source at your site! Consult your radiation control officer in case of any doubt. The user is responsible for the correct labeling of the source and its power supplies, as well as providing safety instructions in the native language of the site!

Note:

With accelerating voltages of less than 20kV, the local dose of 0.1 µSv/h will not be exceeded within a distance of 0.1m from the source. Note that the source runs in vacuum only, i.e. access through an open port is not possible. Normally stainless steel chambers, components and sight glasses with thickness greater than 1.5mm thickness (DN16CF windows) are not permeable.

Chapter 2 Description

2.1 Hardware Description

The complete X-ray source package consists of the X-ray source module XR-50, the power supply XRC1000 and the cooling unit CCX 60.The XR-50 module has a weight of about 10 kg.

The parts of the X-ray source XR-50 are shown in figure 9," page 35 and described below:

- The X-ray source housing with bypass pumping port and cover, a 4-pin feedthrough for the cathode assembly, and "Quick Fit" connectors for the anode cooling and the water-cooled outer jacket. The mounting flange is DN 38 CF.
- A rotatable X-ray source main chassis with source head, anode cage, bypass ring shutter, and fixing seats for the Cu cooling tanks.
- Two oppositely arranged cooling tanks.
- The cathode assembly with filament wire. (figure 11," page 37).
- The anode, which is covered usual half with Al and half with Mg.
- The anode inner tube ("water pipe") with "Quick Fit" connector flanges for water cooling of the anode and small Cu ring for sealing the anode water supply.
- The cone-shaped Cu nose with X-ray source window made from aluminum foil and a cross-talk protection rod.
- A ceramic flange for isolation of the X-ray anode and "water pipe".

Note: Cu gaskets for DN 35 CF are too tight! Use only Cu gaskets for DN 38 CF with min. 38 mm ID. The chamber flange inner diameter has to be 38.4 mm in minimum otherwise contact to water cooling lines will occur.

Note: Check the inner diameter of the flange where the XR-50 will be attached. Estimate the dimensions of welding seams and mu-metal ports!

2.2 Basic Principles

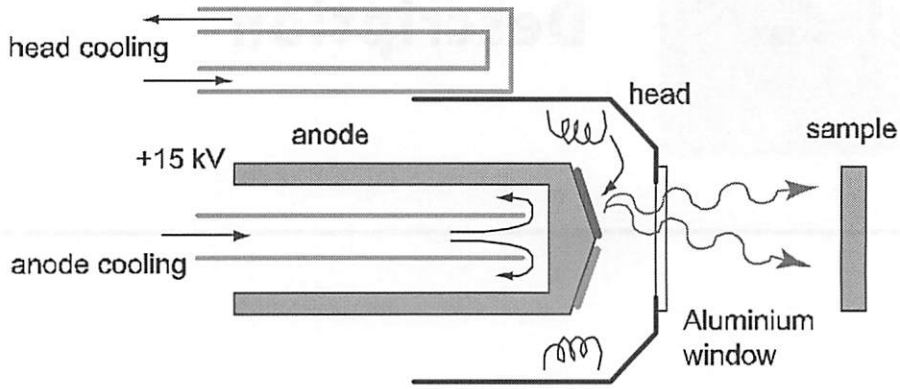


Figure 1 Principle of operation

2.2.1 X-ray photon generation

If a solid state material is bombarded with high energy electrons (greater than a few keV), ionization of electrons in core levels occurs. If these vacancies are refilled by electrons from energetically higher levels, characteristic X-ray radiation is generated. Additionally, Bremsstrahlung, radiation with continuous frequency spectrum, and is also be produced by retarded electrons.

2.2.2 X-ray photon flow

The irradiated area under the anode is elliptically shaped, with an area of 1 to 2 cm^2 depending on anode-sample distance. An unbiased sample current of approximately 0.8 nA per 1 W of Mg K_α X-ray power is generated by irradiating a clean sputtered Ag target. If the photon yield is approximated to
$\eta = 1$ and a photon density of 5×10^{12} s^{-1} cm^{-2} is assumed, 300 Watts of X-ray power can be calculated. A more realistic approximation based on a yield of $\eta = 0.1$ or $\eta = 0.01$ will change the value by the factors 10 and 100, respectively.

2.3 General Information, Principle Setup

2.3.1 Twin anode

The main advantage of a dual anode is that operation with two different excitation energies enables a rapid distinction of Auger electron lines from photoelectron structures. The most commonly employed anode materials are Al and Mg that produce $K_{\alpha 1/2}$ radiation lines at energies of 1486.6 eV and 1253.6 eV, respectively. The natural line width is less than 1 eV; sufficient to determine the binding energies of core levels within 0.2 eV. Low energy X-ray excitation lines (Y M_ζ, Zr M_ζ) are attractive based on their

energies of 132 eV and 151 eV and on their natural line widths of 470 meV and 770 meV, respectively. The radiation energies are intermediate between Al/Mg K_α and the quasi monochromatic UV excitations.

In table 1 on page 38 of the "Appendix" excitation energies, relative intensities, and line widths of the main anode materials are categorized. In table 2 the energy shifts and relative intensities of satellite lines of the main excitations are summarized.

The anode and its inner water tube are interchangeable. Details of the procedure are described in section 5.5 and section 5.8 . The minimum distance between the center of the anode face and the sample is about 14 mm.

2.4 X-Ray Source Voltages and Currents

This section deals with voltages, currents, and powers of the X-ray source. For a better understanding, a block diagram is depicted in figure 2 that shows the source voltages and currents.

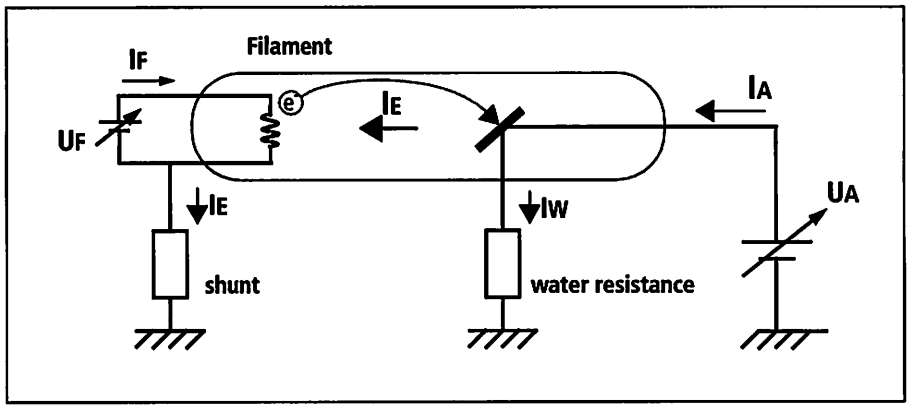


Figure 2 Block diagram of the XR50.

2.4.1 Vacuum conditions

The XR-50 source is UHV compatible. The parts exposed to vacuum consist of high quality stainless steel, very pure copper, tungsten and alumina. The water-cooled outer jackets limits the temperature increase of an irradiated metallic sample during operation to 3 K with respect to the ambient temperature. During operation at maximum power (400 W), a maximum temperature increase at the Cu head of the X-ray source of 30 K is observed under normal cooling conditions. Efficient cooling minimizes intensive desorption from the walls.

The XR-50 will work satisfactorily at pressures below 1 x 10^{-5} mbar. Nevertheless, better vacuum conditions, in the 10^{-8} mbar range or better, are strongly recommended to prevent contamination of the X-ray window and the volume behind the anode. Good vacuum conditions prevent oxidation of the filaments, ensure a longer lifetime of the

anode and X-ray window, reduce the risk of spark-overs between the anode and grounded parts, and enable a longer availability of the X-ray source at full intensity.

2.4.2 Separate and Bypass pumping

The bypass ring shutter at the X-ray source main frame:

- **Must be open if no bypass pumping system is installed!**
- **Must be closed if a bypass pumping system is installed!**

The installation of a vacuum bypass or a separate pumping system are a measure to ensure better vacuum conditions in the anode volume, especially during bakeout. Additional pumping facilities are strongly recommended if harmful or aggressive gases are introduced in the main chamber. The installation of a bypass or separate pumping will reduce aging effects of the anode and the Al window. The most simple solution for a bypass is the installation of a flexible bellows between the XR-50 bypass flange and a suitable flange on the main chamber. More elaborate bypass systems include either ion getter pumps or turbo molecular pumps and a valve which is remotely-controlled for simultaneous venting. The bypass line must be vented simultaneously together with the main chamber to avoid the damage of the Al-window (see section 2.4.3).

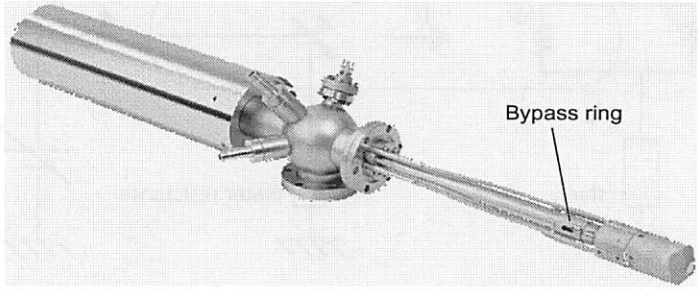


Figure 3 Bypass ring (here open)

2.4.3 Al window

The aluminium radiation window (standard thickness 2 µm) suppresses Bremsstrahlung and prevents the input of stray electrons generated by the filament from entering the energy analyzer. Additionally, the X-ray window acts as a barrier between the main chamber and anode volumes.

Note: Replace perforated X-ray windows to reduce stray electrons and excessive Bremsstrahlung.

A flange on the outer jacket of the source allows evacuation, either together with the analysis chamber or separately via a DN 40 CF (see section 2.4.2). The Al window can be destroyed if a pressure difference between the volumes occurs. A bypass system must ensure that pressure differences (e.g. during regular or emergency venting processes) do not occur.

Besides anode degradation, the contamination of the X-ray window from both sides is the main reason for a reduction in X-ray source intensity. Therefore any dirty processes (e.g. sputtering, deposition, desorption) in the immediate vicinity of the Al window must be avoided in the chamber with the X-ray source. The retraction of the X-ray source from the sample during ion bombardment with a linear translation stage reduces the deposition rate at the Al-window by several orders of magnitude. The installation of a shutter just before the X-ray window and operated by remote control or by hand is an alternative tool for protection. Because of the space occupied by a shutter the X-ray source can not be arranged as close to the sample, which results in a small decrease in the X-ray intensity. The window can also be contaminated from the inside by deposition of anode and filament material or by pump oil from the bypass line. In the case of a system failure (e.g. emergency venting, excessive O_2, turbomolecular pump breakdown), contamination can be significant.

Note: Any visible coloration of the Al X-ray window is a sign for thin films deposited which reduce X-ray intensity. Replace contaminated X-ray windows! Use a z-retractor or shutter to protect the window during ion bombardment or any other dirty processes in the chamber!

2.4.4 Bakeout procedure

With all the cables and water pipes disconnected and the protection cover removed the XR-50 can be baked up to 250 °C. In order to avoid temperature differences in the anode or the cooling tanks of the source it is recommended to remove (blow out) all the water from the anode inner tube and the water-cooled outer jacket before the bakeout starts. This operation can prevent the formation of micro leakages.

SPECS recommends heating tents with IR radiators for bakeout in order to ensure homogeneous temperature conditions without thermal gradients. The use of heating straps and heating jackets is not supported by SPECS because thermal gradients result in the redistribution of desorbed species from hotter to colder surfaces.

Note: Homogeneous bakeout is essential for stable operation and long lifetime of the anode and the whole X-ray source.

2.4.5 Water-cooling

Note: SPECS recommends a closed circulation water-cooling system for protection of the environment. SPECS supports only the use of water as the cooling agent for the XR-50.

Full power dissipation of the X-ray source can only be obtained if the pressure of the cooling water is greater than 3.5 bar and the flow rate is 2.5 -3.5 l/min. The temperature should be maintained at 22 °C. A lower temperature will result in condensation, and flashover to ground inside the water conduit or the protection cover. Higher temperatures results in overload, i.e. an evaporation of the anode material or in a worst case a cracked anode with water injection into the vacuum chamber. Normally the anode cooling and the outer jacket cooling will be performed serially (see figure 10, "The Connection Diagram for the X-Ray Source XR-50," page 36). However, if conditions do not allow a flow rate of 2.5 -3.5 l/min, separate cooling of the outer jacket is possible.

About 1 l/min in this line is sufficient to maintain the specified temperature at the source head.

2.4.5.1 Water resistance

During operation the anode flange and the anode inner tube are at potentials as high as + 15 kV. The anode net power consists of X-ray radiation and heat dissipation. The anode gross power also includes the voltage drop via the water inflow and reflow lines for anode cooling. The water cooling box is grounded. The difference between gross and net anode power will increase with lower water resistance or increase with higher water conductivity.

The difference between gross and net emission currents, the so-called "water current" should not exceed 10 mA. In this case the cooling water in the closed circulation system must be replaced with deionized or distilled water after washing the pipes and the tank to remove any residual deposits. If the water resistance is too large, i.e. < 2 mA "water current" at 15kV, sparks between the anode and water line as well as electrochemical attacks at the anode inner tube, especially at the "Quick Fit" pipe connections, can occur. In this case a small amount of NaCl or the addition of tap water will reduce the resistivity and ensure stable operating conditions. If the "water current" exceeds the limit mentioned above for XR-50 for users with a tap water supply, this type of cooling should not be continued. The installation of a closed circulation system will be required.

Note: Water resistance is an important parameter for stable operation!

2.4.5.2 Circulation diagram

In figure 10, "The Connection Diagram for the X-Ray Source XR-50," page 36, the arrangement of the water-cooling box CCX-50 and the water pipes is shown. The water pipes have to be either 3/4" or
1/2". Note that a particulate filter is a standard part of the input line!

If several instruments are attached to one chiller or one tap (e.g., turbo molecular pumps); the water flow rate, the heat transmission, and the water pressure have to be checked. The different water consumers have to be organized in a shunt arrangement. The conditions summarized in section 2.3.1 and mentioned above have to be fulfilled for stable and secure operation under all different operating conditions and loads in the different lines.

Note: Take care that under all operating conditions the water flow rate, temperature, and water pressure are stable and within the limits!

2.4.5.3 Water quality / Closed circulation system

If a closed circulation system is utilized:

- SPECS recommend the use of deionized water for closed circulation systems to get correct water resistances.

- Follow the instructions made by the manufacturer or supplier of the closed circulation system! Respect the safety instructions!
- Incorporate the control of the closed circulation water-cooling system into the X-ray source interlock system!
- Inspect the water level and quality! Refill or replace water, if necessary!
- Wash and clean the recirculator and the water lines. If there is too much water conductivity, perform some cleaning cycles with tap water before refilling deionized water!
- SPECS recommend the use of an **anti-algeon** to suppress biological activity. For the same reason the use of dark, non-transparent water pipes is advised.

2.4.5.4 Water Quality / Tap water

If tap water is utilized as the cooling agent:

- Water polluted by suspended particles can not be utilized without a filter.
- Water polluted by colored additions should not be used for cooling the XR-50 module.
- Salt water (also with lower concentration) cannot be utilized for reasons of reduced water resistance and increased electrochemical activity!

Note: Never utilize polluted or contaminated tap water for X-ray source module cooling!

2.4.5.5 Contamination of Water pipes

The water pipes can become contaminated on both the inner and outer walls. The main reason for contamination along the inner surfaces are particles and chemical compounds in solution that are deposited as sediments as well as contamination of a biological origin. This process will be intensified if longer periods of X-ray source inactivity take place.

Do not forget to add few drops of anti-algeon agent!

Note: If the X-ray source will taken out of operation for a longer period, remove the water hoses from the XR-50 module to avoid intensive sedimentation! Remove (Blow out) the water from the water pipes inside the module!

The water hoses can also be contaminated on the outer walls depending on the water quality in the laboratory. Under extreme situations the voltage drop which normally occurs via the inflow and outflow from the anode water supply can be established in the sediments on the outer walls. Shorts to the grounded cover plate of the X-ray source can develop. Parts of the plastic water hoses can become inflamed and melt.

Note: If such a incident occurs, the total replacement of the water hoses within the conduit between XR-50 module and water cooling box is strongly recommended! Consult SPECS! Replace the "Quick Fit" connectors! Restart the water-cooling with care!

2.4.6 Use of a Z-retractor

The installation of a z-retractor between the XR-50 and the chamber flange offers the ability to move the whole source from its position for XPS into a parking position for other operations, e.g., ion bombardment, sample annealing, desorption and sample transfer. Retraction of the XR-50 into the parking position allows ion bombardment without sputter deposition onto the Al-window. For delicate samples, which could decompose or change their chemical bonding under X-ray radiation or electron bombardment (polymers, et. al.), a partial retraction of the X-ray source will reduce damage. The use of a z-retractor to avoid thermal stress (essential for other X-ray sources) is not important for the XR-50 because of the efficient cooling of Cu head and main frame.

2.4.7 Residual magnetic field

The XR-50 module head is manufactured mainly from Cu, Al, and other diamagnetic or nonmagnetic materials. SPECS specifies a residual magnetic field at the sample which is below 0.5 μT. A very small magnetic field in the volume between sample, the electron energy analyzer, and the X-ray source module is essential to get X-ray excited photoelectron lines of different kinetic energies from the same element of acceptance area.

2.4.8 Ghost lines and Cross talk

The XR-50 is equipped with a Ag-tipped anode, usually coated with Al/Mg. Therefore Cu L_α breakdown structures that could otherwise complicate the XPS spectra are not expected if the Mg and Al thin films are exhausted. The anodes are manufactured under carefully controlled conditions to guarantee an even and pure coating with the intended thickness. UHV conditions during deposition ensure very low levels of oxygen contamination, avoiding additional photoelectron structures and peak broadening.

Just behind the Al-window a small rod reduces the Al/Mg cross-contamination ("cross-talk") to values below 0.35%. A Cross-talk spectrum is shown in figure 4. The rod is oriented parallel to the groove at the anode top which is separating the two anode sides to each other. The space between the rod and the anode is the most critical place for HV sparks inside the vacuum. Clean and dust free surfaces without sharp edges are recommended.

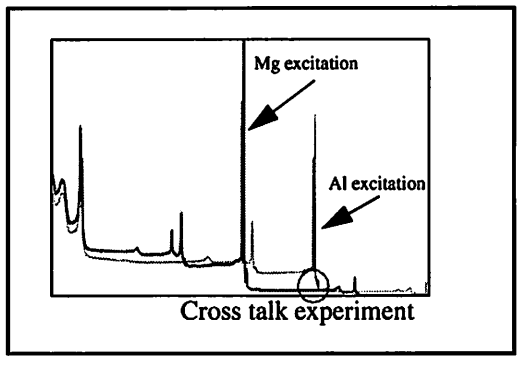


Figure 4 XR 50 Cross talk.

2.5 X-Ray source

2.5.1 Anode

Anode:	positive high voltage
Anode material:	Al, Mg, Al/Mg; other materials upon request
Anode base material:	Ag-tipped
Anode voltage:	+ 15 kV Max., 0 to 40 mA (with respect to ground)
Power dissipation:	1 kW Max.
Continuous load:	**Al 400 W, Mg 300 W**
Anode cooling:	water, 3.5 to 5 bar, > 2.5 l/min, 15 - 22 °C
Head cooling:	water > 1 l/min, 15 - 22 °C
Anode sample distance (regular)	15 mm

2.5.2 Cathode

Cathode:	Tungsten (spiral)
Power consumption:	Max. 30W

2.5.3 Operation Range

Working pressure:	better than 10^{-5} mbar (regular)
Bakeout temperature:	250 °C, without cable connections and protection cover

2.5.4 Setup

Vacuum pumping:	via analysis chamber or via separate pumping line
Outer jacket:	Cu pipes and Cu blocks, water-cooled
Anode:	interchangeable on flange DN 38 CF
Radiation window:	Al, thickness about 1.7 -2 µm, pressure-proof to 1 mbar difference
Mounting flange:	DN 38 CF, larger flanges upon request
Max. diameter:	37.8 mm
z-retraction (optional):	50/100 mm
Copper gaskets:	DN 38 CF
Weight:	10 kg

2.5.5 Test Conditions and Results

UHV system with Quadrupole.	Source was leak tested with He after a bakeout of 8h at 200°C.
Spherical Energy Analyzer:	Mode B=const.
Cross Over for double anodes:	less than 0.35%
Photo electron current (achieved):	280 nA (Ag, sputter-cleaned, 300 W Mg K_{α}, for the used test system the photo electron current may differ depending on sample distance
Residual magnetic field at	below 0.5 µT depending on sample position

2.5.6 XR-50 for X-ray Monochromator

The XR-50 can be altered for use as a X-ray monochromator source (XR-50M with separate manual). Consult SPECS if such a modification is intended.

2.6 Power Supply Units for Operation

SPECS has specially designed modules for operation together with the XR-50, the power supplies XRC1000 and CCX 60.

Attention

Mind the safety hints given on page 2!!!
Beware! Lethal high voltage is applied to the water within the hoses during operation.

Warning: It will take 3 minutes after the high voltage is turned off until residual voltages in the source, respectively power supply are reduced to zero. Wait at least 3 minutes before opening the protection cover and disconnecting any cables from the power supplies or the X-ray source.

The water line consist of two PTFE hoses in a plastic covered, reinforced conduit. The Cooling Control Unit CCX 60 opens the water inlet valve, if the COOLING button of the X-ray power supply XRC1000 is depressed. The internal flow rate meter (visible from the front panel) will enable the Operate function of the X-ray power supply via the interlock line.

The XRC 1000 supplies all voltages and currents needed for the operation of the source XR50. This power supply is also capable of powering other X-ray sources.

Please check the corresponding manuals for further details.

Chapter

3

Installation of the X-Ray Source & Power Supply Units

The X-ray source is supplied for installation without bypass pumping (see section 2.4.2 , 'Separate and Bypass pumping" on page 8). If separate or bypass evacuation is required, the bypass ring shutter figure 9," page 35 must be rotated in such a way that the pumping holes of the volume around the anode are closed and the pumping port has to be connected to a separate or bypass pumping system.

3.1 Test prior to Installation

Note: Prior to installation of the XR-50 the following checks are recommended:

1) Measure the electrical resistance on both sides of the cathode (filament feedthrough flange, figure 9, "X-Ray Source XR-50," page 35), nominal: < 0.5 Ohm. Take into account that two of the feedthrough pins are shorted in the source. These two pins go to the middle filament wire. Selecting a cathode means using one side of the circular shaped filament wire.

Beware! For small resistances the measured value depends strongly on the device and the method.

2) Check whether their cathode assembly is electrically isolated from source body.

3) Check the Al radiation window (figure 11, "Source Head XR-50," page 37) for any damage and correct fit.

4) Check whether the anode flange and inner water tube are electrically isolated from source body.

3.2 Installation of the source

No distinct position for installation of the X-ray source is specified. However, the slender design allows the arrangement of other analysis modules around the sample. Install the source to avoid conflicts with other components.

If the XR-50 is mounted in a spherical chamber with the energy analyzer on top the feedthrough for the cathode supply should be aligned horizontally.

If a bypass or separate pumping lines are planned, the water connectors of the X-ray module chassis should be aligned on top.

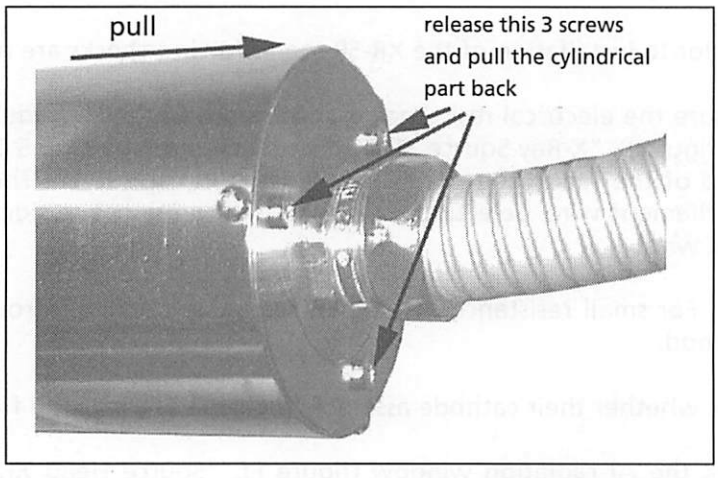
If a z-shift retractor is to be installed, check for space and the best position. Z-shifts supplied by SPECS are equipped with a DN 38 CF flange that has a doubled bolt hole circle to ensure the best orientation.

3.3 Water Connection

For the normal connections as refer to figure 10, "The Connection Diagram for the X-Ray Source XR-50," page 36.

Full power dissipation of the X-ray source can only be obtained if the pressure of the cooling water is between 3.5 and 5 bar and the flow rate is higher than 2.5 l/min (section 2.4.5).

1. Connect the Cooling Control Unit to the water supply. The water connection should be outfitted with a additional shut-off valve.
2. Release the 3 screws at the rear of the water plug (not on the cylindrical part) to push the water connectors and the HV cable outside the cylindrical housingt.



The inlet and outlet of the anode water cooling (plastic covered, reinforced conduit) should be carefully checked and connected to the correct tube pipe connections (shroud plug and socket). Arrows at the water connectors of the anode water flange and on the hoses show the direction of the water flows out from the unit into the anode, and back from the anode into the cooling unit.
Normally the middle pipe connection at the anode inner tube flange means ,water into the anode.

Note: Pay attention to the direction at the anode water flange. Mistakes can result in damage the anode due to reduced cooling!

Mind the safety hints given in section 5.8 , 'Exchange of the water inlet (anode inner tube)" on page 33 and on page 2!!!

3. The rate of water flow should not be set below 2.5 l/min. Operation at maximum power can not be safely be achieved at lower flow rates. Overload can result in an evaporation of the anode material or in a worst case, a cracked anode with water injection into the vacuum chamber.
4. Connect the anode water reflow at the rear panel of the Cooling Control Unit to one of the water connectors of the XR-50 main housing. The other water connector should be connected to the reflow flange of the closed circulation system or the water outlet. **There is no specified direction of the water flow in the XR-50 main body.**

3.4 Electrical Connection

For the usual connections refer to figure 10, "The Connection Diagram for the X-Ray Source XR-50," page 36.

The standard electrical supply for the X-ray source consists of two 19"-rackmount modules with serparate manuals:

- the High voltage power & emission regulation unit XRC1000 and
- the Cooling Control Unit CCX 60

Attention

Mind the safety hints given on page 2!!!
Warning: It takes 3 minutes before all high voltages are absent. Wait at least 3 minutes before disconnecting any cables from the power supply or the X-ray SOURCE!

1. The high voltage unit has to be connected directly to the mains supply.
2. The high voltage line between the cooling unit and the anode (cable no.7) is the most critical connection. Careful installation is necessary.
   - The high voltage connection between the Cooling Control Unit and the High Voltage Supply has to be fixed with stress reliefs on both sides.
   - Connect the X-Ray source with a HF low impedance cable to the power supply ground. Large contact areas are important. This connection will protect the sensitive electronic units of your system.
   - The connection from the cable no. 7 (HV to anode) to the banana plug has to be fixed with M2 screw.
   - The housing of the high voltage cable no. 7 (HV to anode) has to be connected with the back side of the cover plate of the source. **A perfect connection of the high voltage cable protects your life, your electronic equipment and the XR-50 source.**
3. The safety interlock for the cooling water (comes from the Cooling Control Unit CCX 60), the safety HV-cover switch (of the X-ray source) and the vacuum interlock have to be plugged into their respective

sockets ("WATER", "HV-GUARD" and "VACUUM") at the rear panel of the X-ray power supply. **Because the vacuum interlock is not part of the SPECS x-ray equipment, pin 1 and 2 at the vacuum interlock socket has to be activated by a vacuum interlock unit, e.g., a vacuum gauge.**

4. The water cooling unit has to be connected as in figure 10, "The Connection Diagram for the X-Ray Source XR-50," page 36.

Chapter

4

Operation of the X-Ray Source

Attention

Mind the safety hints given on page 2!!!

For the initial commissioning, after each venting of the vacuum system or if there have been bad vacuum conditions a careful setup of the X-ray source is recommended.

4.1 Initial Setup of the source

Note: Some steps described here result in pressure increases due to gas desorption; the pressure will gradually decrease with continuous operation. Each step should be maintained as long as the pressure is no longer decreasing, especially at higher voltages. Too rapid of an increase of the high voltage can lead to violent plasma discharges and sparking, damaging the XR-50 source and electronics.

4.1.1 Soft Start Option

If your supply has a soft start ramp push-button, simply push the button. The **ramp** push-button can only be used in conjunction with the optional remote interface. Upon pushing this button the high voltage and the emission current are ramped slowly for both anodes. This function is usually used to start up the source automatically after each bakeout. The LED is on if the ramp is in progress.

If spark-over or other failure occurs the ramp will start over 2 times, and will stop if the third ramp fails, with a blinking **Ramp** lamp. Try soft start operation again and watch the display during the soft start to verify the failure. The status after a successful soft start is off. For more details see the user manual of the XRC1000 remote interface.

4.1.2 Manual Initial Setup

1. Check the vacuum conditions, the vacuum should be better than 10^{-6} mbar. (The live time of filament and anode depend on vacuum conditions!)
2. Set the high voltage and emission current to zero.
3. Switch the supply on.
4. The interlock **"Water"** is blinking.
5. If any of the other interlock LEDs are unlighted check the appropriate connection, refer to the fault finding guide in the power supply manual.
6. Depress the **water** button. The cooling water circuit is switched on, i.e. the valve for the water flow is opened. After all the air bubbles in the cooling lines have disappeared the cooling LED switches off.
7. Select the anode by pushing the button **Anode 1** or **Anode 2**.
8. Push **Standby**. This will set the filament current to the standby current of about 1.5 A within few seconds.
9. Choose a small voltage (2 - 3 kV) and switch **the HV on**. Increase the HV (1000V steps within few minutes) up to about 8kV.
10. Switch anodes (respectively the cathodes) and repeat item 9.!
11. Set the emission current to a small value (about 5mA) and start the Emission Regulation Circuit by pushing **Operate**.
12. You can watch the filament current, filament voltage and power supplied to the anode in the power supply display by pressing the inscribed push-buttons.
13. Increase the high voltage and the emission current (step width: 1000V) to 10kV 10mA values for both anodes as following:
    Increase the emission current up to 20 mA within few minutes by monitoring the chamber pressure! Set the emission current back to 5 mA for the next high voltage step.
14. Maintain a value of 10kV and 20 mA for at about 1/2 hour of operation to degas the source.
15. Switch anodes (respectively the cathodes) and repeat item 14. to degas also the other anode surface and the surrounding space!
16. After stable operation (pressure ok, no sparking) the voltage and power can be increased slowly (50W/5 min, 500V steps) to the desired values, depending on your desired working conditions, e.g., 12.5kV and 20mA = 250W.

If stable operation of the X-ray source was observed over an extended period, the procedure described here can be abridged.

4.2 Normal Operation

1. Requirements for normal operation:
   "Manual Initial Setup" on page 22 was done and no vacum break after this procedure was happen.
   Check the vacuum; it should be better than 5 x 10^{-7} mbar.
2. **Power** on the XRC1000 (switch left side at the front panel). The display comes up and the interlock lamps indicate the actual status. The lamp for the water interlock is on.
3. If any of the other interlocks are on check the appropriate connection, refer to the fault finding guide in the power supply manual.
4. Power on your water equipment (chiller etc.), if no remote control is installed.
5. Push the water button. The cooling water circuit is switched on, i.e. the valve for the water flow is opened. After a few seconds the interlock indicator lamp switches off.
6. Select the anode by depressing the button **Anode 1** or **Anode 2**.
7. Push **Standby** (right side). This will set the filament current to the standby current within few seconds. You may check this pressing I_F button while monitoring display.
8. Choose the desired voltage and switch **HV on** (red button). Wait for the end of the voltage ramp.
9. **Set** the emission current to the desired value and start the emission regulation circuit by pushing the **Operate** button.
10. You can watch the total current, power, filament current and filament voltage supplied to the anode in the power supply display by pressing the inscribed buttons. Wait until the system has become stable (monitoring the pressure) before beginning any experiments.

In case the high voltage is automatically switched off due to an interrupted water flow (e.g. air bubbles) or due to a vacuum failure the procedure should be repeated.

Beware:

In the "Operate" mode if I_{Fil} is blinking, the "current limit" is active, then the filament assembly is shorted or the preset high voltage is not sufficient for the chosen emission current. Check filament resistance! In the second case it is necessary to increase the high voltage or decrease the emission current. Otherwise the lifetime of the filament will be shortened or cathode material evaporated onto the anode faces.

- Never short the interlock system for HV Guard and Cooling!
- Never operate the X-Ray source without cooling! The anode coatings will be evaporated immediately and the anode can be cracked.

4.3 Switching Off the X-Ray Source

1. To turn off the power supply push the **HV** button. HV will be switch off and the filament will go into **Standby** mode (The LED at this button is active).
2. Push **Standby** to switch off the filament (LED in this button is off).
3. Wait one minute then turn off the water circuit by depressing the **Water** button. The water cooling should not be continued, otherwise the anode will be cooled down and become the coldest surface of the analysis system. Intensive condensation of contaminants at the anode surface would be the unintended result.
4. Switch off the power supply.
5. Turn off the water the cooling unit. For a longer non-operational period it is recommended to remove the water supply and to remove the water from the pipes.

4.4 Bakeout of the X-Ray Source

Attention

Mind the safety hints given on page 2!!!
Warning: It takes 3 minutes before all high voltages are absent. Wait at least 3 minutes before disconnecting any cables from the power supply or the X-ray SOURCE.

Refer to figure 10, "The Connection Diagram for the X-Ray Source XR-50," page 36.

1. Loosen the grounding cables. Loosen the screws of the protection cover (back plate of the cover too).
2. Pull back the tube of the protection cover.
3. Relieve the connecting cables (HV) and water hoses.
4. Detach the cooling water connection.
5. Place the protection cover (anode plug) outside the bakeout zone.
6. Remove filament supply (loosen the fixing screw first).
7. Prior to bakeout it is very important to remove the remaining water from the anode and the main housing of the module.

The X-ray source can be baked up to 250 °C.

After the bakeout reassembling of the X-ray source should be carried out in reversed order.

4.5 Hints for Operation

Depending on the anode material an operating voltage exists for the X-ray source at which the X-ray quantum yield is in its maximum for a certain fixed anode dissipation power. The specific radiation intensity on the sample surface depends on the X-ray power as well as on the X-ray-anode-sample distance. The X-ray-anode-sample distance is determined by the sample geometry. The radiation intensity depends on the applied high voltage in the X-ray source. Sample currents generated by 300 Watts, 15 kV and 20 mA and by 300 Watts, 10 kV and 30 mA will be distinct. This is reasonable because below the ionization energy (approximately 1500 eV for Al) no characteristic X-ray radiation can be emitted, even by using very high anode power. On the other hand it is well-known that the ionization cross section decreases with increasing energy. Between these two extrema there is an optimum. The optimum lies between 10-13 kV for Al and 13-17 kV for Mg. The yield curves show a flat region around the maximum. Normally operation at a voltage of 12.5 kV is enough to get optimum radiation for both anode materials. It is also possible to determine the state of aging of the anode with the aid of curves of the X-ray quantum yield versus applied high voltage at constant anode power. The sensitivity achieved in ESCA depends on the sensitivity of the energy analyzer and the specific radiation density of the characteristic X-ray emitted from the sample surface.

Strong outgassing organic samples can lead to a contamination of the anode with carbon or other materials. The same effect will be caused by frequent operation of the analysis system under bad vacuum conditions. This contamination layer reduces the X-ray intensity because the electrons that excite the anode material must penetrate this layer first. This effect is distinguishable from other influences, e.g. change of amplification of the multiplier, if the intensity yield curve is plotted versus applied high voltage at constant anode power. With a contaminated anode the maximum will tend towards higher energies. If the contamination is too strong then the maximum will even disappear within the working range of the X-ray source up to a high voltage of 15 kV.

Use of the Al radiation window eliminates the possibility of contamination of the anode. The transmission of the Al window will be influenced by sputtering of the sample in front of the source as well as from the evaporation of tungsten from the filament during operation or because of fusing. A 0.2 µm Tungsten layer on the window absorb the same intensity as 2.5 µm Aluminium. Each anode exchange or filament replacement should be performed in association with a window exchange.

Chapter 5 Maintenance

SPECS offers a complete cleaning, overhaul and testing of your XR 50 X-ray source on request. This service includes anode and filament replacement, anode inner tube replacement or refurbishment if necessary, and a complete testing with a specification report.

Important Safety Information:

- **Note that products returned to SPECS for repair or maintenance must be free of harmful substances (e.g. radioactive, toxic, caustic or microbiological), or otherwise, the contamination has to be declared.**

5.1 Spare parts

Spare parts	filament, anode, Al-radiation window, anode inner tube (water inlet part), hose connections, filter

Please contact SPECS (support@specs.de) for prices and delivery time.

5.2 Fault Finding

5.3 Power Supply Fault Finding Guide

Please check the power supply fault finding guide in the power supply manual.

5.3.1 HV sparks

If HV sparks occur the power supply will switch off the HV go into standby mode. At the beginning of operation and after venting or after the replacement parts some sparks may occur. Normally the occurrence of these HV sparks will decrease over time.

Possible sources for HV sparks are:

- bad ground connections
- bad vacuum conditions
- water leakage inside the protection cover
- the protection cover itself (PTFE isolation)
- the HV cable or the HV supply
- the anode
  (The distance between the anode and Al window rod which suppress the crosstalk is especially critical. Overload, contamination, dust particles or cooling problems can cause HV sparks that result in the formation of small craters. This is accompanied by an evaporation of the anode material or, in the worst case, a cracked anode with water injection into the vacuum chamber.
- the Al window

Attention

Mind the safety hints given on page 2!!!

Warning: It will take 3 minutes before all high voltages are absent. Wait at least 3 minutes before disconnecting any cables from the power supply or the X-ray source.

If the frequency of sparks increases it is absolutely necessary to find out the reason. Please try to find out whether the sparks are outside or inside the source (vacuum). Contact SPECS prior to dangerous test procedures!

1. Do the sparks effect the pressure inside the vacuum chamber or not? Consider that even in case of HV sparks outside the source module the vacuum reading at the controller can be influenced by electromagnetic pulse EMP, resembling a pressure increase.
2. Do the sparks occur in operate or standby mode? Does the occurrence of sparks depend on the absolute value of the high voltage?
3. Is the PTFE shield inside the protection cover intact, does it show HV traces or is it dirty or wet?
4. Switch off the HV and check the HV cable for electrical isolation.

WARNING!
HAZARDOUS VOLTAGE! DANGER FOR LIFE!

5. Do sparks occur in standby mode?
   If sparks still occur:

HV sparks are in the supply, the protection cover or the HV cable! Separate the source by disconnecting the supply line step-by-step.

5.4 X-ray Source Check

Note: Place the source that was removed from the main chamber on clean and spacious table and use the water bypass tubes and the water inlet as support points. Caution: If the anode and the water inlet flange are removed for maintenance the source head will become the third support point because of a different weight-distribution balance. Avoid damage to the filaments!

If the XR-50 is removed the following source checks are recommended:

- Cathode OK? (resistance, check by appearance)
- Al radiation window OK? (holes, contamination either from sample or anode side) see also "Hints for Operation" on page 25. If the Al window was damaged by a pressure difference, the lost Al foil must be located otherwise electrical contact between the anode and the grounded XR-50 body can occur.
- Is the anode centering bushing (Vespel) contaminated? Measure the resistance between anode and body.
- Is the anode centered or misaligned? The Cu cathode cap (see figure 11," page 37) must be removed. If damaged or malfunctioning parts are identified, replace or refurbish these components otherwise valuable experimental time will be lost!

5.5 Exchange of the Anode

When exchanging of the anode it is not necessary to remove the X-ray source from the vacuum system. Refer to figure 10 and figure 11 in section 6.1 .

Attention

Mind the safety hints given on section 1!!!
Warning: It will take 3 minutes before all high voltages are absent. Wait at least 3 minutes before disconnecting any cables from the power supply or the X-ray SOURCE.

Remove all connections from the source (see "Bakeout of the X-Ray Source" on page 24). It is necessary to remove the anode and water inlet flange from the X-ray source body (the ceramic isolator can stay on the body).

The following procedure must be carried out:

1. Remove the flange screws of the anode/water inlet.
2. Remove internal part (water inlet flange) of the anode.
3. Remove the anode. Note the Al/Mg orientation!
4. Replace the used copper gasket with a new one.

5. Insert the new anode with Mg/Al in the correct orientation.
6. Replace the used Cu water sealing ring
   (a new one is supplied together with every new anode; shape is not important, it is only a water seal!).

Beware:
Fasten the screws until the slit between the flanges become invisible. Reassemble the source in reversed order.

Please also see section 5.9 , 'Recommendations for a new anode and water inlet" on page 34.

5.6 Exchange of the Cathode

When exchanging the cathode it is necessary to remove the X-ray source from the vacuum system.

Attention

Mind the safety hints given on page 1!!!
Warning: It will take 3 minutes before all high voltages are absent. Wait at least 3 minutes before disconnecting any cables from the power supply or the X-ray SOURCE.

Remove all connections of the source (see "Bakeout of the X-Ray Source" on page 24) and remove the X-ray source. Refer to figure 10, "The Connection Diagram for the X-Ray Source XR-50," page 36 and figure 11, "Source Head XR-50," page 37 and to the figures below.

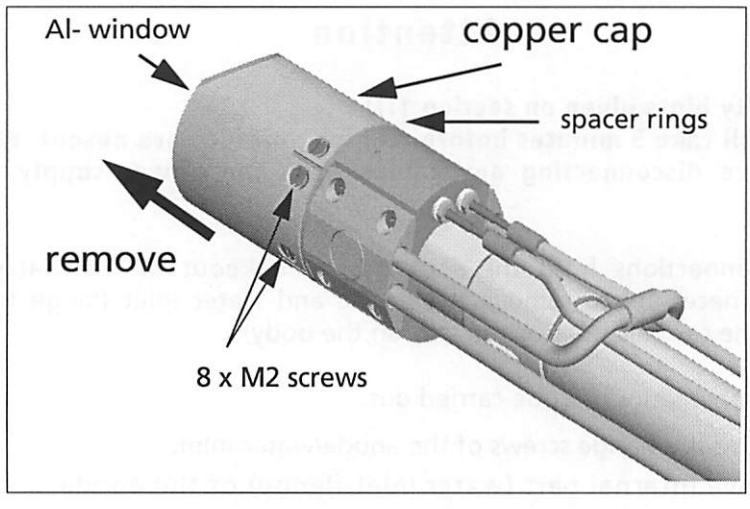


Figure 5 XR-50 source head

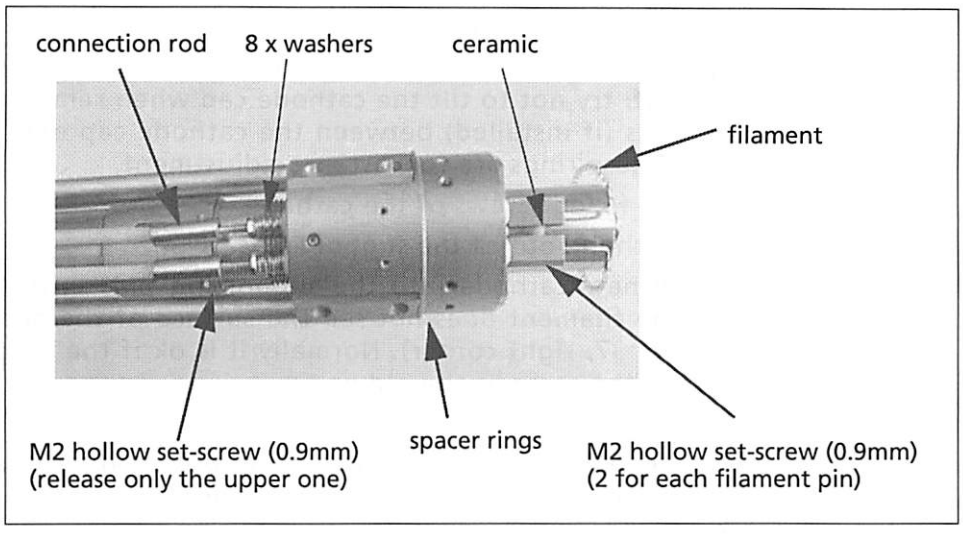


Figure 6 XR-50 source head without cap

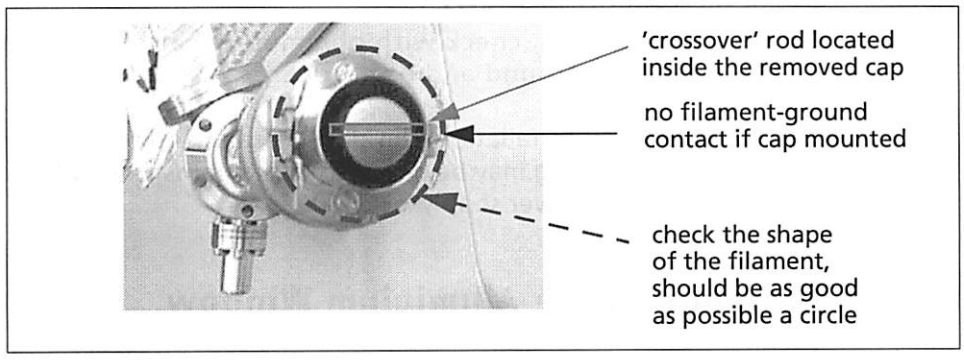


Figure 7 XR-50 source head filament shape

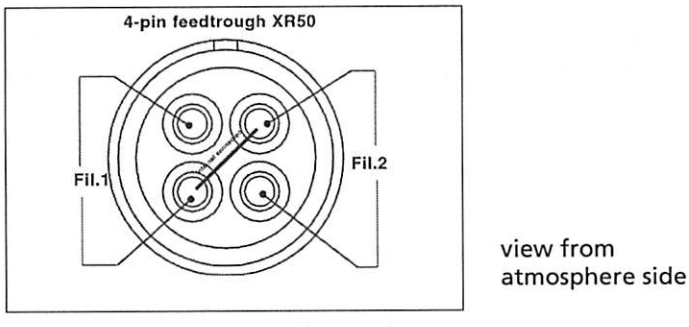


Figure 8 Filament feedthrough

The following procedure must be carried out:

1. Loosen the cylindrical screws.
2. Carefully pull off the cathode cap. The cathode cap should be pulled straight off; try not to tilt the cathode cap when removing it. Keep the spacer rings (if installed) between the cathode cap and the head body in place. These rings are for distance adjustment.
3. Loosen the fixing screws of the cathode.
4. Pull the cathode out of the support pins.
5. Insert the new cathode into the supporting pins until the uppermost part of the filament does not see the surface of the anode (see figure 11," page 37, right corner). Normally it is ok if the height of the new filament is the same as the old one.
6. Fix the M2 screws.
7. Make sure that the filament has an approximately circular shape. If necessary, carefully bend the filament support pins.
8. Carefully mount the cathode cap onto the head of the X-ray source. The crossover rod below the Al-window has the same orientation like the anode. Push the cap all the way down so that it has the same distance as before. Remember to keep the spacer rings in place.
9. Fix the cylindrical screws.
10. After installation, check with ohmmeter that none of the filament pins has a short to ground and not broken.

Please see "Test prior to Installation" on page 17, also. Adjustment of the $I_{Standby}$ and I_{MAX} filament current setting may be necessary if filaments from other manufactures are used (see manual of the power supply XRC 1000)

5.7 Exchange of the Aluminium Window

When exchanging the Al window it is necessary to remove the X-ray source from the vacuum system.

Attention

Mind the safety hints given on page 1!!!
Warning: It will take 3 minutes before all high voltages are absent. So wait at least 3 minutes before disconnecting any cables from the power supply or the X-ray SOURCE.

Remove all connections of the source (see "Bakeout of the X-Ray Source" on page 24) and remove the X-ray source.

1. Remove the Al window by loosening the guard ring and pull out the window.
2. Carefully insert the Al window into the groove of the copper cooling cap and press the window ring slightly. Make sure that the Al window lies flat on the cooling cap and is not bent.

3. Fix the Al window with the guard ring. Cover the window during this process with a flat smooth part.
4. Insert the X-ray source.

Please see "Test prior to Installation" on page 17 and "Recommendations for a new anode and water inlet" on page 34.

5.8 Exchange of the water inlet (anode inner tube)

The inner part of the anode (water inlet) is strongly influenced by corrosion (see "Corrosion of the water inlet parts" on page 34). This effect is enhanced for deionized water. As long as the front surface of the connectors (shroud plug and socket) is still smooth there is no danger. If this surface shows deep craters the inner part should be changed.

Warning

If the water connections are leaky, water with high voltage will drop into the source cover. The high voltage will be automatically switched off.
Mind the safety hints given on page 1!!!

When exchanging the inner part of the anode it is not necessary to remove the X-ray source from the vacuum system.

Attention

Mind the safety hints given on section 1!!!
Warning: It will take 3 minutes before all high voltages are absent. Wait at least 3 minutes before disconnecting any cables from the power supply or the X-ray Source.

Remove all connections of the source (see "Bakeout of the X-Ray Source" on page 24). Following procedure must be carried out:

1. Follow the procedure given in "Exchange of the Anode" on page 29 item 1 up to "Replace the used copper gasket with a new one."
2. Inspect the anode and insert the old one, if no damage is visible.
3. Replace the used Cu water sealing ring on the anode flange (a new one is supplied together with every new anode or water inlet part). Insert the water inlet part.
4. Fasten the screws until the slit between the flanges become invisible. If necessary apply slightly excessive torque to the screws.
5. Reassemble in reversed order.

Please also see "Test prior to Installation" on page 17 and "Recommendations for a new anode and water inlet" .

5.9 Recommendations for a new anode and water inlet

Note: These recommendations should be followed to prevent a decrease of the anode performance.

5.9.1 Length of the water inlet (anode inner tube)

Mechanical force should never be required while installing anode inner tube. The length of the inner tube should match the anode exactly otherwise the water flow will be reduced and the anode will degrade quickly. Blow trough one of the connections as a continuity check. The pressure to blow trough should be similar to that to fill a balloon.

5.9.2 Corrosion of the water inlet parts

The inner tube as well as the water pipe connections corrode because of their connection to + 15 kV anode voltage. Electrochemical corrosion at the water pipe connections causes a decomposition of the "Quick Fit" couplings. Please check the connections occasionally. Replace the anode inner tube and the "Quick Fit" connectors if water leakages are observed. Sedimentation processes take place especially in the top of the tube. This sedimentation effect is accelerated after the X-ray source was taken out of operation for a long period. The sedimentations should be removed mechanically to guarantee effective cooling of the anode.

5.9.3 Cooling with tap water

While cooling with low temperature (10 - 14° C) tap water with the cooling effect on the main body of the x-ray source module can be felt. However, depending on environmental conditions, low temperatures can will force water condensation and flashover to ground inside the water conduit or the protection cover. The recommended temperature for cooling the x-ray source is 15 - 22° C (see section 2.5.1 , 'Anode" on page 13. Higher temperatures results in overload, i.e. an evaporation of the anode material or worst case in a cracked anode with water injection into the vacuum chamber

5.9.4 Closed circulation water-cooling systems

Especially during high power operations (> 300 W), check the cooling temperature which should be lower than 22 °C. Note that blocked filters in the water line can reduce the water flow dramatically resulting in temperatures at the anode at which material will be evaporated. Therefore it is strongly recommended to tune the water flow meter to a level with a flow rate higher than 2.5 l/min.

Chapter

6

Appendix

6.1 Pictures and Drawings

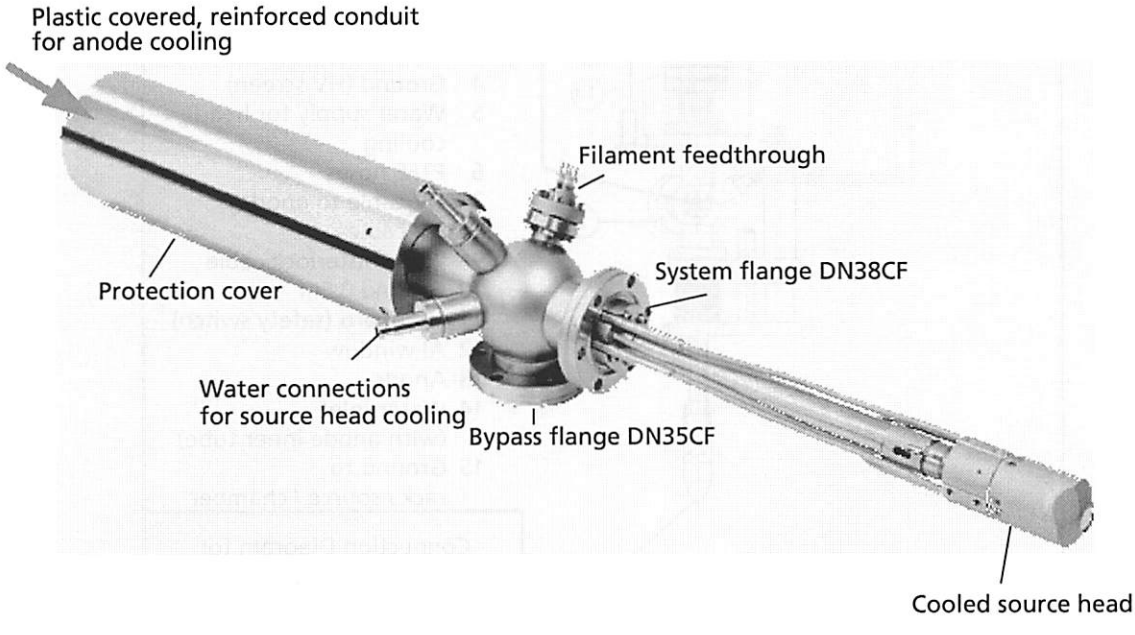


Figure 9 X-Ray Source XR-50

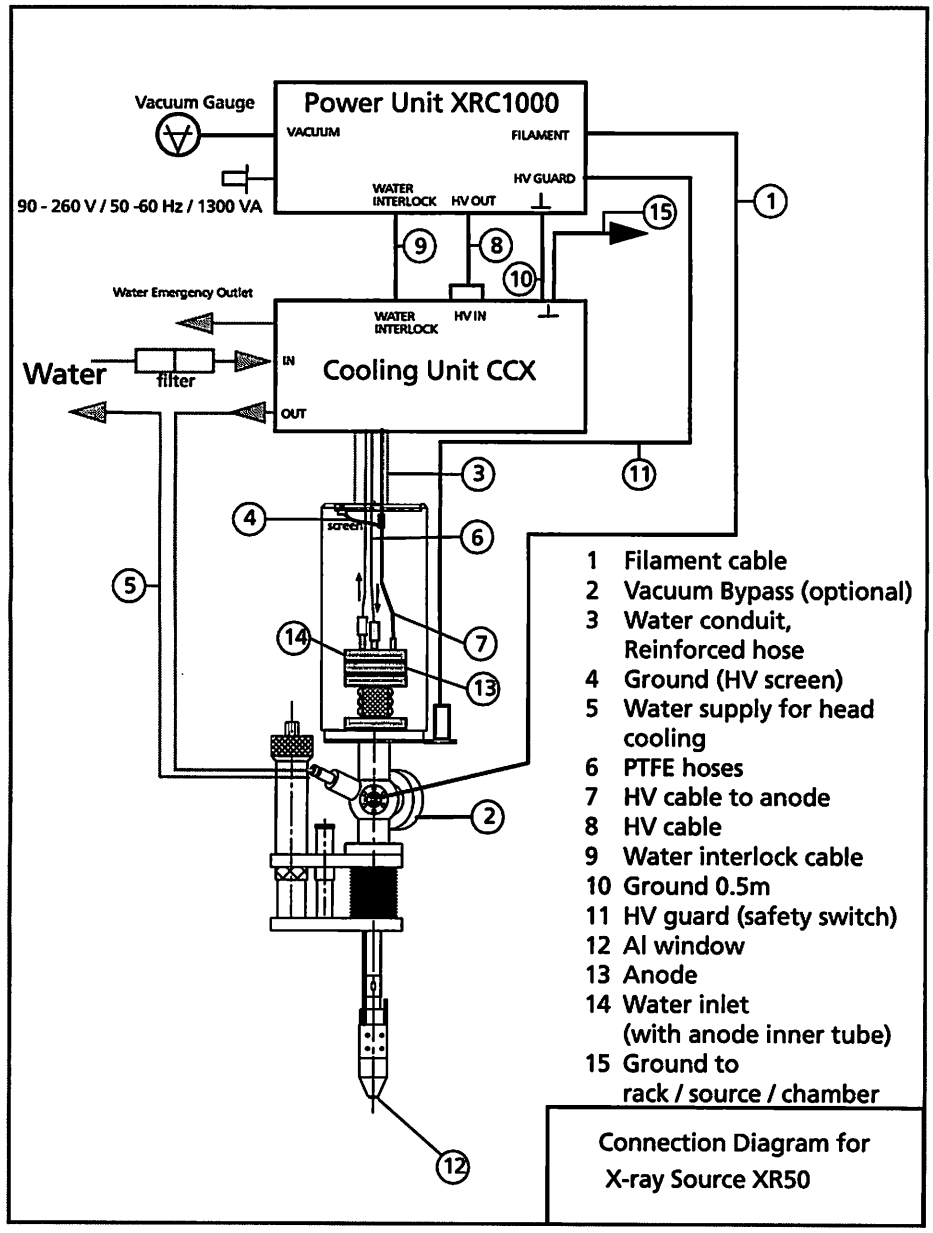


Figure 10 The Connection Diagram for the X-Ray Source XR-50

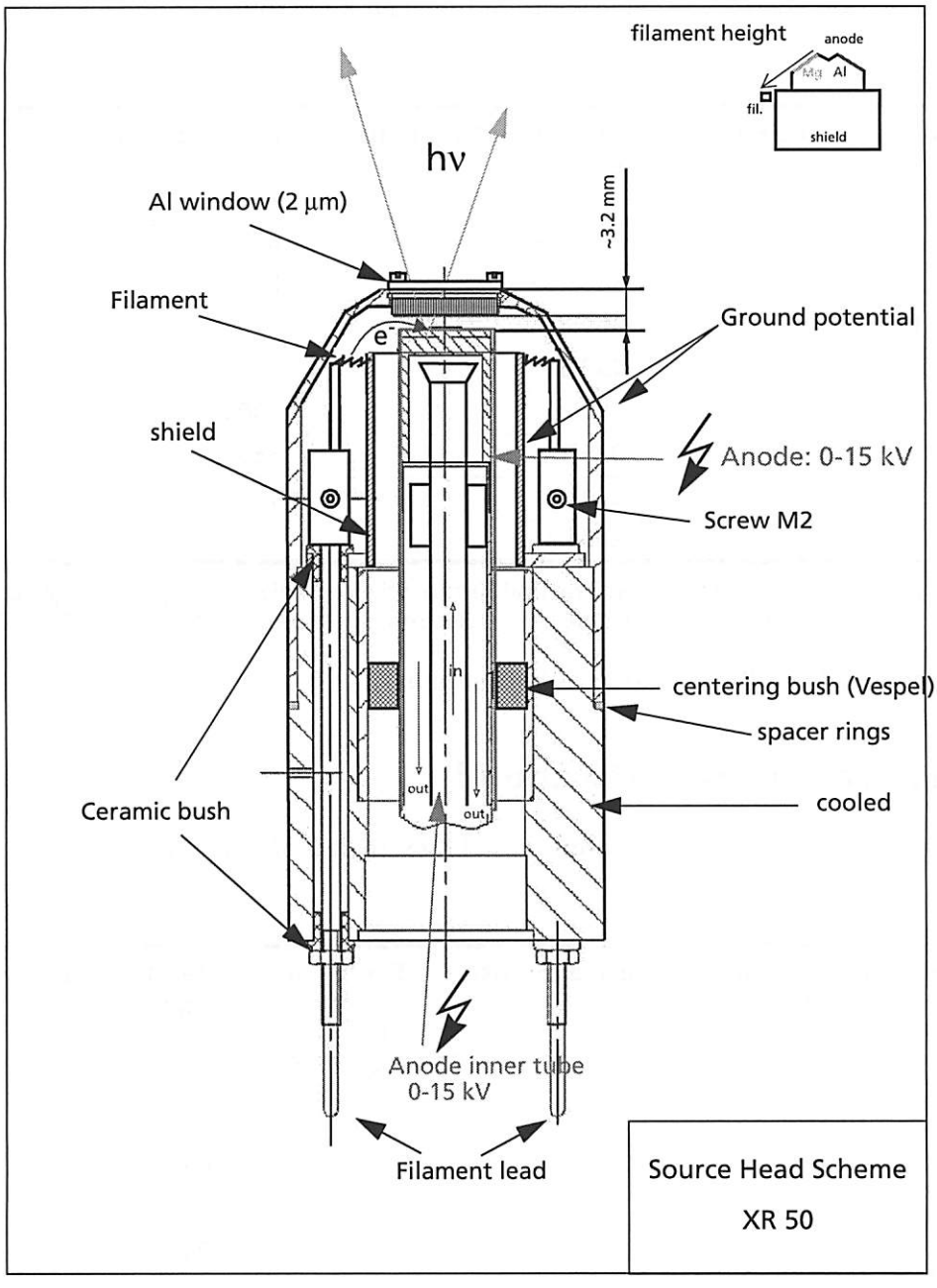


Figure 11 Source Head XR-50

6.2 Excitation energies of different anode materials

Excitation energies and line width of the main X-ray source anode materials

Element and Line	Excitation Energy (in eV)	Line width (in meV)
Mg $K_{\alpha 1/2}$	1253.64	680
Al $K_{\alpha 1/2}$	1486.65	850
Zr M_{ζ}	151.4	770
Y M_{ζ}	132.3	470
Si K_{α}	1739.5	1000
Cu L_{α}	929.7	3800
Zr L_{α}	2042.4	1700
Ag L_{α}	2984.4	2600

Ref.: D. Briggs and M.P.Seah, Practical Surface Science Analysis, Wiley, Chichester, p.50, p.128
H. FellnerFellner-Feldegg et. al., J. Electron. Spectrosc. Rel. Phenom. 5 (1974) 643.

Table 1: Main X-ray source radiation lines

6.3 Satellites of Mg and Al

Energy shifts and relative intensities of Kα satellites of Mg and Al

Line	Energy shift (in eV) Mg	Relative Intensity (in %) Mg	Energy shift (in eV) Al	Relative Intensity (in %) Al
$K_{\alpha 3}$	8.4	8.0	9.8	6.4
$K_{\alpha 4}$	10.1	4.1	11.8	3.2
$K_{\alpha 5}$	17.6	0.6	20.1	0.4
$K_{\alpha 6}$	20.6	0.5	23.4	0.3
K_{β}	48.7	0.5	69.7	0.6

Ref.: J.F. Moulder et. al., Handbook of X-ray Photoelectr. Spectrosc., Physical Electronics, Inc., 1995, p. 18.

Table 2: Mg/Al Kα satellites

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